Radiation: Medical Diagnostic Uses

DELL F. DULLUM, *M.D.*, Berkeley

• **Use of radiologic procedures in diagnosis now contributes a significant dose of ionizing radiation to our population. Whether this presents a real risk to the health of the present and future population cannot be determined with certainty from evidence available at this time. Hence, it appears proper to keep the dose to every patient as low as practical consistent with good medical practice. The average dose can be significantly reduced by having more physicians apply the known techniques for minimizing the exposure to the patient.**

The medical profession has a direct professional concern for the actual or potential risk of damage resulting from the radiation that patients are exposed to during diagnostic x-ray procedures, since these procedures constitute the largest single man-made source of genetically significant radiation our population is now exposed to.

It is important to distinguish two distinctly different types of radiation effects—somatic effect, in which the damage affects the health of the person irradiated, and genetic effect that is capable of producing constitutional defects in future progeny over many generations.

ALL LIVING THINGS have existed in an environment of *natural background radiation* since the beginning of creation. Since 1895, medical and industrial uses of x-rays and radium have contributed significantly to this dose, and radioactive fallout has added a little since 1945. It is important to consider the relative dose to the human population from these various sources. Of major importance is the genetically significant dose to the gonads from the moment of conception to the age of 30 (when reproduction is estimated to be 50 per cent complete). In a recent authoritative report[4] this 30-year genetically significant dose was estimated at about 3.7 r (range 2.4 r to 5 r) from natural background, about 4.2 r (1.2 r to 7.2 r) from medical diagnostic uses, and about 0.05 r from radioactive fallout from all weapon-testing to date.

The radiation the bone marrow receives is important as a possible cause of leukemia. In the previously mentioned report[4] the average marrow dose over a 70-year period was estimated at about 8.5 r (5 r to 12 r) from all natural sources, about 5 r (3.5 r to 7 r) from medical diagnostic uses, and 0.3 r from radioactive fallout from all atomic weapon tests to date, the latter dose applying when equilibrium is finally reached after a period of many years.

The radiation to which the population is exposed arises from either natural background or from man-made sources, each contributing approximately half of the genetically significant radiation. Of the man-made portion of this genetically significant radiation, medical uses (almost entirely from diagnostic x-ray procedures) contribute approximately 85 per cent, radioactive fallout, television, and luminous clock and watch dials each contribute approximately one per cent, while occupational and industrial exposure contribute the remainder.

Thus it is apparent that the medical uses of radiation are responsible for a major portion of the total radiation dose of both genetic and somatic significance. Estimates of the dose contributed by medical uses are extensively reported in the United Nations Report.[14] These estimates are admittedly subject to many variables, and the accuracy of these estimates has been questioned by many authorities.

Submitted June 6, 1960.

BIOLOGICAL EFFECTS OF RADIATION

The concept of a *threshold dose* of radiation—that is, the dose below which there will be no injury—is of significance, for if there is no threshold for a certain effect, then any dose, no matter how small, will have some effect. Most authorities agree that there is no threshold for genetic effects. However, the question as to whether there is a threshold for somatic effects such as leukemia has not been agreed upon because most somatic effects are known to be reversible at least to some degree.

The *proportional relationship between dose and effect* is also of practical significance. Although the frequency or magnitude of an effect ordinarily increases as the dose increases, it is often impossible to determine whether the increase is strictly proportional, that is, "linear." Such relationship is more and more difficult to prove as the dose is decreased to lower and lower levels, making the prediction of the effects of very small doses quite uncertain.

PERMISSIBLE RADIATION DOSE

Consideration of allowable radiation dose was concerned initially with safe working conditions. It was assumed that the radiation worker had a certain

tolerance, below which there would be no risk of injury. Subsequently the concept of a Maximum Permissible Dose (MPD) was developed, based on the belief that even the least amount of radiation probably produces a biological effect. Although the possibility of injury could not be ruled out, it was believed that a dose could be stated (MPD) for which the risk is so low that it is not expected to cause appreciable bodily injury to a person at any time during his lifetime. However, it was urged that the exposure should be kept as low as possible consistent with practical protective measures. This MPD was not to be all used up merely because it was permitted.

More recently the concept of MPD has been broadened to include the danger of genetic damage to the population at large and to include radiation from sources other than occupational exposure, such as the natural background radiation and the radiation wilfully applied to patients by the healing profession. Recommendations were formulated by advisory agencies such as the National Academy of Science (NAS) in 1956[7] and more recently in 1960[8]. I quote from the latter report: " . . . the committee continues to recommend that for the general population the average gonadal dose accumulated during the first thirty years of life should *not* exceed 10 r of man-made radiation, and should be kept as far below this as practical." The 10 r limit includes the man-made radiation wilfully applied to patients by the healing professions. While the NAS recommendation for the total population is based primarily on the risk of genetic damage, the report states that "it seems that the limitation of exposure suggested by the committee on genetics should be adequate for purposes of establishing that no perceptible somatic effect will occur, although theoretically minor shortening of life span or a slightly increased incidence of tumors cannot be excluded as a possibility."

The National Committee on Radiation Protection (NCRP) recently made recommendations[10] concerning MPD for the total population from the standpoint of somatic as distinguished from genetic effects. I quote the report in part: "Although it is not our responsibility to determine the exact level, we believe that the population permissible somatic dose from man-made radiations, *excluding medical and dental sources* (italics mine), should not be larger than that due to natural background radiation, without a careful examination of the reasons for, and the expected benefits to society from a larger dose. . . ." It goes on to say: "Recommendations regarding a maximum permissible level for medical and dental exposures to the patient are not given because for somatic effects of radiation the possible harm and prospective benefits occur in the same individual in contrast to radiation involving genetic material. The committee urges that continual caution be exercised to maintain radiation for medical and dental purposes at the lowest feasible level."

The Federal Radiation Council (FRC), formed in 1959 by Public Law to provide federal policy on human radiation exposure, formulated a Radiation Protection Guide (RPG)[4] for the guidance of federal agencies in radiation protection activities. The guide relates to normal peacetime operations and ". . . is not intended to apply to radiation exposure resulting from natural background or the purposeful exposure of patients by practitioners of the healing arts."

It has been noted above that the dose to the patient from medical uses may or may not be included in the consideration of MPD for the total population from either a genetic or somatic standpoint. The MPD recommended by the NAS,[8] which is based primarily on the risk of genetic damage, includes the dose to the patient in medical uses. In this case the MPD specifies the average per capita dose and not the dose that may be applied to the individual patient. Other agencies such as the FRC[4] have excluded from consideration the dose to the patient on both an individual and average per capita standpoint on the basis that these depend on the clinical situation and are matters of medical judgment. This in no way implies that the dose to the patient is of no significance, as all agencies are specific in their recommendation that this dose from medical uses be kept as low as possible consistent with good medical practice.

The somatic and genetic effects of radiation have been extensively documented in the United Nations Report.[14] It will be recalled that radiation produces genetic damage by way of mutations in the genetic material in the reproductive cells of the gonads. These mutations are almost always undesirable, are cumulative, permanent and heritable, being passed on to future generations. Radiation does not cause a different type of mutation or damage; it only increases the frequency of mutations, adding to the total number of the many mutations constantly occurring from many other sources. Therefore the detection of genetic effects specifically due to radiation in doses we are concerned with here is essentially impossible. Although the effect may in some cases be expressed as a specific congenital defect, most authorities agree that the genetic damage of major importance will be expressed as general effects such as a decreased life-span, a decreased well-being, and a decreased fertility of future generations. These general effects will in most instances be delayed and spread over many generations. For this reason it will not be possible to evaluate the genetic damage by merely looking for any increasing incidence of monsters or other detectable defects in either the present or future generations.

The somatic effects of radiation of the type and dose of the usual diagnostic procedure include among others the possible risk of an increased rate of aging, a shortened life span and an increased incidence of neoplasm. Investigators[14] have demonstrated those effects in animals. Although a life-shortening effect has not been documented in man in the dose range of current diagnostic procedures or permissible occupational exposure, it is not reasonable to assume that this effect could not or does not exist.

MEDICAL USES

The medical and allied professions can be justly proud of their role in not only the development and expansion of the uses of radiation in the healing professions but also the development of improved equipment and techniques designed to keep the radiation dose to the patient as low as possible. I quote the NAS report of 1960[8]: "The medical and dental professions are commended for their continuing efforts to reduce diagnostic and therapeutic radiation exposures to the lowest levels consistent with sound medical practice."

The medical profession was told as recently as 1959 by Scott,[12] a prominent radiologist, that the gonadal dose from diagnostic examinations can be reduced to one-fifth the present dose, and that ". . . the key to implementing the safe use and control of medical radiation lies in the education of all practicing physicians in the fundamentals of genetics, radiobiology and radiology."

The radiation the medical profession uses is no different from any other kind of radiation. It is not reasonable to imply or state that radiation is harmless or even beneficial merely because it is applied by physicians. It is equally not reasonable to state that since there is presumably biological effect from even the smallest dose of radiation, a medical use is therefore a hazard. Risk and benefit are relative terms. The practical recommendation has been more wisely stated thus: That the radiation be used, either in diagnosis or therapy, with due consideration for a *reasonable balance between the expected benefit and the estimated risk.* The radiation is beneficial only in relation to the expected benefit to either the patient or to society as a whole. This, of course, is the basis for the medical use of radiation.

If the exposure is not necessary to the actual needs of the medical situation, it is *unnecessary radiation* and should be avoided. This implies that a procedure which is not clinically justified should not be done. It also implies that for any particular diagnostic procedure any radiation that is not required (for example using a larger field than is actually necessary) is *unnecessary radiation.*

From evidence available at present it is obvious that the patient should not be denied the many advantages of radiation in either diagnosis or therapy provided the risk, whatever it may be, is balanced by the expected benefit. It follows that any physician permitting, requesting or actually performing the procedure must assure himself that the procedure is necessary. It also follows that the procedure should be conducted with the necessary skill and competence to keep the dose to the patient to the minimum and provide a maximum of information or benefit.

The somatic effect of radiation as used in diagnostic radiology varies principally with the dose and the region of the body irradiated. Any measures that decrease the dose, such as removing the useless soft radiation by proper filtration or by limiting the field to the actual area of interest by proper cones, will decrease the risk. These protective measures are particularly important in examinations involving the trunk. While the risk of somatic injury in the usual diagnostic procedure is probably negligible on an individual basis, considering the population as a whole the aggregate effect of even this small risk—such as an increased rate of aging, possible life shortening and a possible increased incidence of malignant disease—may be of considerable statistical significance.

The genetic risk of diagnostic x-ray relates directly to the dose to the gonads at any time before the end of the reproductive period of life. The genetic dose is a pooled dose, based on the total of the individual gonad doses but expressed as an average per capita dose. For a population group of one million, an annual average per capita gonad dose of one-tenth r can be based on varying doses to varying segments of the group, such as 100 r to each of 1,000 patients, 10 r to each of 10,000 patients, or one-tenth r to each of the million, with equal total genetic risk to the future progeny of this population group. Thus a single patient having a pelvimetry contributes as much gonad radiation and genetic risk to the population group as three thousand other patients who have a single chest film. About 85 per cent of the total population gonad dose from diagnostic procedures is contributed by the six or seven procedures involving direct irradiation of the lower abdomen and pelvis, although these procedures make up only about 10 per cent of the total volume of diagnostic radiology. Even for some of these pelvic examinations a small protective shield over the scrotum or ovaries where feasible would obviate nearly all the risk even though the protected gonads were within the larger field of direct radiation.

Of particular interest is the risk of antenatal maternal diagnostic procedures involving the abdomen and pelvis. Ford and coworkers[5] indicated that irradiation of the fetus during gestation correlated with

an increased incidence of leukemia and other malignant diseases in childhood. The foregoing and other studies by Stewart and coworkers,[13] emphasize the need to minimize the dose to the fetus. The developing embryo is most sensitive to radiation in the immediate post-fertilization stage. As very early pregnancy may not be apparent even to the patient, elective diagnostic procedures involving the lower abdomen or pelvis of females during the active child-bearing age should preferably be limited to the ten to twelve days just after the beginning of the menstrual period.

Pelvimetry presents a unique risk in that there results not only a maternal regional and a fetal total body irradiation of somatic significance, but also genetically significant radiation to both the maternal and the fetal gonads. Osborn and Smith[11] estimated that pelvimetry in England and Wales in 1955 contributed 18.6 per cent of the genetically significant radiation from diagnostic procedures even though this examination constituted only one-tenth of one per cent of all radiographic examinations. This estimate was based on the assumption that pelvimetry was performed in less than 60 cases per 1,000 live births and that a 3-film technique was used.

The radiation hazard from chest x-ray examinations must be considered not only because of the large number of such examinations but also because the gonad dose may be decidedly increased by improper or careless techniques. If the gonads are protected from the primary beam either by limiting the beam to the chest area by a proper cone or by placing a protective shield over the lower abdomen and pelvis, the gonads will receive only scattered radiation. If the entire trunk is "sprayed" by the primary beam, the effect is essentially total-body irradiation and the gonad dose may be increased by a factor of a hundred or more.

The gonad dose in chest filming varies considerably with the use of different kinds of equipment. The gonad dose from a single 14 x 17 inch posterior-anterior film averages about one-tenth mr (thousandth of an r). The gonad dose from minifilms is increased by a factor as great as 20 when equipment of the older type is used, and by a factor of about 5 when the newer mirror-optics equipment is used. The foregoing estimates of gonad doses are based on using good equipment and confining the primary beam to the chest area.

The gonad dose in chest fluoroscopy varies decidedly with many factors such as the size of the shutter opening, but averages about 20 mr per minute. Thus one minute of chest fluoroscopy, using good technique, ordinarily gives a gonad dose equal to that from two hundred ordinary chest films.

A possible somatic hazard from chest x-ray procedures, including minifilms, cannot be excluded in even optimum radiation protection circumstances. The area of the body ordinarily irradiated in a chest film includes not only a large portion of the total active bone marrow but also the organs and tissues of the upper abdomen which also are relatively more sensitive to radiation. The total dose to any one patient having repeated examinations could be considerable. Moreover, the number of persons at risk is large as chest radiology is a large fraction of diagnostic practice. The UN Report[14] estimates that even if only 10 per cent of the population is examined each year by minifilm, this would contribute 20 per cent of the total population marrow dose from all types of diagnostic procedures. Other conventional chest films and chest fluoroscopy contribute about 10 per cent. These compare with an estimated 40 per cent contribution by examinations of the gastrointestinal tract and a 4 per cent contribution to the total marrow dose by x-ray examinations of the teeth.

INFORMATION AND EDUCATION

It is essential that any program of information and education regarding radiation hazards be conducted in a manner which will not cause a patient to either refuse or be denied a necessary x-ray procedure because of any unreasonable alarm or fear on the part of the patient or the physician. Boek and coworkers[2] in 1958 conducted a survey to determine the attitude of the general population in regard to routine chest x-rays. Of those questioned, 88 per cent considered the routine examination very important, 9 per cent were uncertain, and 3 per cent were opposed. Of the 12 per cent who were uncertain or opposed, less than half mentioned radiation exposure as the reason for their opinion.

The American College of Radiology, representing a segment of the medical profession most directly concerned with the medical uses of radiation, published in 1956 a special bulletin[1] to "clarify and comment upon" the reports issued by the National Academy of Science[7] and the British Medical Research Council[6] concerning the biological hazards of radiation. This special bulletin states in part:

"The American College of Radiology will cooperate with all efforts to encourage medical authorities of this country to initiate a vigorous movement to reduce the radiation exposure from x-rays to the lowest limit consistent with medical wisdom and in particular, that they take steps to assure that proper safeguards always be taken to minimize the radiation dose to the reproductive cells. It is obvious that anyone who owns x-ray equipment should be trained in its safe use, should know the output of his machine, should check these outputs at regular intervals and should be thoroughly familiar with the radiation dosage to those who are exposed."

Dr. Eugene P. Pendergrass, delegate to the American Medical Association House of Delegates from the Section on Radiology at the A.M.A. Clinical Session in December 1959 introduced the resolution approved by the delegates which called for programs of radiation safety inspection to be carried out under auspices of the local medical societies. That resolution, in its entirety, reads:

"WHEREAS, the benefits of radiological diagnostic exams are vital and irreplaceable in importance in the practice of clinical medicine, and

"WHEREAS, these benefits should be obtained with a minimum of radiation exposure and economy of radiation use, therefore be it

"*Resolved*, that the A.M.A. urge to all county and state medical societies the establishment and promotion of programs of inspection and testing of medical fluoroscopes and radiographic equipment. It is suggested that these programs be sponsored and arranged by the said county and state societies for their members."

The American College of Radiology has prepared and made available excellent authoritative material dealing with radiation protection. *A Practical Manual on the Medical and Dental Use of X-ray with Control of Radiation Hazards*[1] has been given wide distribution. A set of slides illustrating methods to control the hazards of x-ray examinations has been prepared by the college and is available for loan from the college or from the California State Department of Public Health. The American College of Radiology, in cooperation with the U. S. Public Health Service, supported by a grant from the Rockefeller Foundation, has prepared an excellent film *Radiation: Physician and Patient.*[1] Prints of this film may be obtained for showing from the college or from the California State Department of Public Health.

PUBLIC HEALTH AGENCIES

The California Atomic Energy Development and Radiation Protection Law has been summarized in a previous publication[3] with particular reference to the registration of sources of ionizing radiation as used by the medical profession in California. The California State Department of Public Health has already registered most of the users of radiation (physicians and others) in California and collected a large amount of information from them.

The data collected included much that concerned risk to the patient, that is, the many factors which contribute to or minimize *unnecessary* radiation. These include the type of practice, the type and general condition of the equipment being used, filtration of the primary beam, availibility of cones and collimating devices to limit the field of radiation, and the type and number of the potentially high-risk procedures performed at the installation. Evaluation of these factors will allow a reasonable estimate of the risk to patients examined among the many installations. An evaluation by the physician in charge of the installation may lead to his voluntary correction of those deficiencies he has noted and reported. The evaluation will be of use to public health agencies as a basis for determining the need for future radiation protection programs and their desirable scope.

Although the department has broad authority and responsibility to investigate any public health hazard, the recent radiation legislation requires only registration and has granted no *new* inspection or enforcement authority. At the time of this writing several local governments within California have enacted regulations which establish standards of equipment and practice and which provide for inspection and enforcement at the local level. Others are developing such regulations. Data provided by statewide registration will be made available to official state and local governmental agencies having a valid interest and responsibility in radiation protection. These data will be considered confidential within these state and local governmental agencies except for broad statistical purposes.

In the development of radiation protection programs, state and local public health agencies will request and welcome a cooperative program of consultation and assistance with the medical profession. The profession has in the past contributed to the essential leadership and guidance in developing standards of protection and principles of good practice in the use of radiation. A continuing guidance and support to promote profession-wide acceptance and compliance with these standards will be even more essential. The progressive training and education in radiation within public health agencies will depend not only on governmental budgetary and personnel support but also on the administrative, technical, and professional support of the medical and allied professions. As the experience of public health agencies increases in this field they can give gradually increasing support to those radiation protection programs initiated and developed within state and local medical societies. The hazards of radiological diagnostic procedures will decrease as techniques are improved and as more and more physicians apply them and the already known techniques for minimizing the patient's exposure. Equally, the benefits to patients and society will increase as safe and well-supervised radiation facilities are expanded and made available to the entire population. The public health responsibility at the state and local level will be one of encouraging the development and use of radiation by the healing professions in keeping with clinical needs, while at the

same time encouraging and promoting a program which will protect the patient, the general population, and future generations from the *risk of unnecessary radiation* not required or necessary to the medical needs of the population.

St. Mary's Hospital, 2200 Hayes Street, San Francisco.

REFERENCES

1. American College of Radiology: (a) A comment on The Biological Effects of Atomic Radiation—Summary Reports, 1956, 20 North Wacker Drive, Chicago 6, Illinois. (b) A Practical Manual on the Medical and Dental Use of X-rays with Control of Radiation Hazard, Price 25 cents. (c) Radiation protection slides, $10.00 or on loan. (d) Film: Radiation: Physician and Patient, On loan.

2. Boek, W. E., Schults, H. H., Park, G. D., Cushman, D. S., and Parsons, Carolyn H.: Routine chest roentgenograms; fears and practice, N. Y. State J. Med., 59:3403-3407, Sept. 15, 1959.

3. Dullum, D. F.: Radiation: Registration of sources, Calif. Med., 92:198-200, March 1960.

4. Federal Radiation Council Report No. 1—Staff Report: Background Material for the Development of Radiation Protection Standards, May 13, 1960, 58016—U. S. Dept. of Commerce, Washington, D. C., 1960.

5. Ford, D. D., Patterson, J. O. S., and Trauting, W. L.: Fetal exposure to diagnostic x-rays, and leukemia and other malignant diseases in childhood, J. Natl. Cancer Inst., 22: 1093-1104, June 1959.

6. Medical Research Council: Hazards to Man of Nuclear and Allied Radiation, HMS Stationery Office, London, 1956.

7. National Academy of Sciences, National Research Council: Biological Effects of Atomic Radiation: Summary Reports, Washington, D. C., 1956.

8. National Academy of Sciences, National Research Council: Biological Effects of Atomic Radiation: Summary Reports, Washington, D. C., 1960.

9. National Bureau of Standards, U. S. Department of Commerce: Handbook 59, Permissible Dose from External Sources of Ionizing Radiation, Government Printing Office, Washington, D. C., Sept. 1954.

10. National Committee on Radiation Protection and Measurements—Report of the Ad Hoc Committee: Somatic radiation dose for the general population, Science, 131:483-486, Feb. 19, 1960.

11. Osborn, S. B., and Smith, E. E.: The genetically significant radiation dose from the diagnostic use of x-rays in England and Wales, Lancet, 1:949-953, June 16, 1956.

12. Scott, W. G.: The clinical radiologist and the problems of radiation hazards, J.A.M.A., 170:77/421-428, May 23, 1959.

13. Stewart, A., Webb, J., and Hewitt, D.: A survey of childhood malignancies, British Med. J., 1:1495-1508, June 28, 1958.

14. United Nations Scientific Committee on the Effects of Atomic Radiation, General Assembly, Official Records, 13th Session: Supplement No. 17 (A/3838), Columbia University Press, 1958.

***Comment* by R. R. NEWELL, M.D.**

Concerning Dr. Dell F. Dullum's essay, Radiation: Medical Diagnostic Uses:

Dr. Dullum's thesis is that the hazards of diagnostic radiology are offset by the benefits of more efficient diagnosis leading to more effective treatment. This makes you think that the patient is submitting to a small but reasonable injury. The careful arithmetic of the National Committee on Radiation Protection has persuaded many persons to the same belief—even the members of NCRP itself. When it is written: "You may expose a person to a total of 15 r in a year, but not if this makes his total to date more than $(N-18) \times 5$ r, N being his present age," what should one think except that more would hurt him? That is not what the NCRP is trying to say, however. The most that we *can* say is that we do not know *but that* more could hurt him. We have calculated the chance of injury, but we've never *observed* any from such doses. If our calculations are correct the injury from, say, twice the MPD is unobservable. To increase the morbidity rate of leukemia to one-twentieth per cent per year (10 times normal) apparently required an exposure of 150 r to 250 r at Hiroshima, or in England about twice that much radiant energy as it was given as a larger therapeutic dose to only a part of the body. In these cases the injury was observable because more than a thousand persons were under observation after exposures exceeding the MPD by a factor of 10 to 50 or more.The genetic injuries are unobservable, too.

What we are demanding is not mere hygiene, it is discipline. We are demanding that radiologists use radiation effectively and for a proper purpose, and then only as much as is necessary. We are demanding that industrialists not let their radiation get to any of their employees above a certain amount or to others above a certain smaller amount. This will keep radiation injuries from appearing, and will keep our theoretical conscience clear about the calculated chances, both for the person irradiated and for the genetic future of the race. MPD is like the highway speed limit, except that on the highway we *can* observe the injuries.

The MPD is not a health rule; it's an operating rule.

R. R. NEWELL, M.D.

San Francisco

* * *

***Comment* by DR. DULLUM**

I have the following comments to make in reference to Dr. Newell's comments:

The NCRP, in establishing a MPD for occupational exposure, recommended a limit of 12 r per year, provided the accumulated exposure did not average more than 5 r per year after the age of 18. The NCRP states that this MPD presents a risk which is so low

that it is not expected to cause appreciable injury to the individual. The MPD is not intended as an arbitrary level below which there is no possibility of injury or above which there is certainty of injury.

However, my article is concerned principally with the radiation dose to the patient. It is well known that a single diagnostic examination can give a total dose to the patient which is greater than the dose equivalent to 5 r total body dose, the *annual* limitation suggested for the radiation worker. It is also quite generally agreed that a dose of 5 r or even less is under certain circumstances associated with significant increase in the incidence of leukemia and other malignancies in the irradiated individual.

I am afraid that Dr. Newell's comments might give the impression to the hurried practitioner that there is no real risk of injury below doses of 150 to 250 r, as it took exposures of this magnitude or of even greater magnitude to portions of the body to produce an increased incidence of leukemia, an increase which is really not significant as leukemia is rare even if the incidence is increased.

The purpose of the article is to show that even though we cannot observe or accurately predict the extent of injury from radiation, we do know that there is some biological effect from even the smallest amount. Therefore it seems wise to use only as much as we need to use. I do not know whether Dr. Newell is personally demanding discipline of the radiologists. I did not intend that my article imply that this was the next step in radiation protection.

DELL F. DULLUM, M.D.